Appendix A

Literature Related to the Potential Impacts of Storm Water Discharges

Exhibit A–1. Literature Related to the Potential Impacts of Storm Water Discharges

Study	Description	Results
Jones et al. (1997)	Macroinvertebrate and fish communities were used to assess the ability of urban BMPs to mitigate Storm water impacts in a suburban watershed. A total of eight practices were assessed including wet ponds, dry ponds, a retrofitted culvert, and a riparian park. The study area is Neabsco Creek in Prince William County, VA., located in a rapid growing suburban jurisdiction in the Washington D.C., metro area. The area has undergone substantial development in the past 20 years and has been accompanied by the use of BMPs to control Storm water impacts. The reference site is Quantico Creek, also in Prince William County, whose watershed is occupied by a unit of the National Park System and the Quantico Marine Base. The watershed is almost entirely forested.	Alterations in the stream macroinvertebrate community in the suburban Neabsco watershed were clear at all sampling stations even when EPA Rapid Bioassessment Protocol (RBP) index values were near reference levels. Taxa richness was consistently lower in the suburban streams particularly in the key indicator groups: stoneflies, mayflies, and non-hydropsychid caddisflies. In general, the data suggest that appropriately designed and properly sited BMPs can provide some mitigation of Storm water impacts on stream communities. However, no BMPs were able to restore the full complement of macroinvertebrate families found in the reference watershed. The resulting communities reflect a fundamental alteration in stream biotic diversity, structure, and function.
Barret et al. (1996)	Examined the impact of highway construction on Danz Creek, Travis County, TX, an intermittent stream that flows in a natural channel and through the construction corridor.	A review of literature shows that, in general, changes in water quality are the result of an increase in suspended sediments discharged from construction sites. The higher suspended solids levels result in reduced diversity and density of fauna in the affected area. Fourteen samples from ten storms were collected at each of two monitoring sites. The greatest differences between upstream and downstream concentrations are shown by suspended solids, turbidity, iron, and zinc. Although accumulation of sediment in the creek occurred during this period, by the end of the study period the creek below the highway had returned to preconstruction conditions. Even though the effects on Danz Creek were temporary, there is concern regarding the effects of construction on the water quality in the Edwards Limestone aquifer. The Danz Creek lies on the recharge zone and therefore, higher concentrations of suspended solids could be expected to enter the aquifer during the period when runoff from the construction site occurred.

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Masterson and Bannerman (1994)	Study to determine the impacts of Storm water runoff on five urban streams in Milwaukee County, Wisconsin. The authors analyzed storm sewer outfall, stream water quality, bottom sediment, whole crayfish tissue, semipermeable polymeric membrane devices (SPMDs), benthic macroinvertebrate surveys and habitat.	Study results show that the urban streams are not meeting their biological potential and recreational classifications as designated by the WDNR. Levels of suspended solids, bacteria, heavy metals, oil and grease, and PAHs were detected in Storm water discharges and stream water that exceeded water quality criteria. Urban streams exhibited a significantly lower diversity of fish species and a majority of the organisms are pollutant tolerant species of fish and macroinvertebrates. Benthic macroinvertebrate bioassessment scores indicated moderate to severe impairment. The study also found a correlation between the extent of urban land use and biological degradation and limited recreational uses. Three of the five streams studied have 100 % urban land use and were the most degraded. Two of the streams have approximately a 50 % urban and non-urban land use and supported a healthier population of aquatic organisms. The reference site supported the most abundant and diverse fish and invertebrate community in accordance with its 100 % non-urban location. Furthermore, high PAH and heavy metal concentrations (lead, in particular) were found in urban whole crayfish tissue samples. SPMD results confirmed that pollutants that tend to bioaccumulate (lipophilic pollutants such as lead, PAH, pesticides, zinc) are discharging into the streams.
Barret et al. (1993)	A review and evaluation of literature pertaining to the quantity and control of pollution from highway runoff and construction.	Highway construction may cause changes in turbidity, suspended solids concentration, and color of receiving waters. The extent and persistence of the changes varies from site to site. However, turbidity and suspended solids concentrations are much greater after construction begins. When construction impacts on stream quality are detected, they are usually transitory. Prevention of erosion during construction is important to minimize the effects on receiving waters. Vegetative stabilization is the most effective method for reducing construction impacts.

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Study	Description	Results
Lopes and Fossum (1995)	The chemistry and toxicity of urban Storm water, streamflow, and bed material in the Phoenix, AZ area were characterized to determine if urban Storm water could degrade the quality of streams. The objectives were to characterize the chemistry and acute toxicity of Storm water from drainage basins with urban and undeveloped land use and of streamflow from the Salt River; identify the phases of Storm water (oil, grease, suspended solids, dissolved trace metals, and dissolved organic compounds) that are causing the toxic effect; and characterize the chemistry and acute toxicity of bed material from drainage basins with urban and undeveloped land use and ephemeral streams that receive urban runoff.	First-flush samples from urban drainage basins appeared to be more toxic than flow-weighted composite samples, and Storm water was more harmful to fathead minnows than to water fleas. The most toxic Storm water samples were collected from the drainage basins with residential and commercial land use, and the toxicity probably was due to surfactants and other constituents leached from asphalt and resealant. Toxicity was generally due to organic constituents. In urban drainage basins, bed-material samples collected from areas where Storm water accumulates appeared to be more toxic than from areas where Storm water does not accumulate.
Campbell (1994)	Storm water treatment ponds in the Orlando, FL area were studied to determine if fish that live these ponds contained significant concentrations of cadmium, nickel, copper, lead, and zinc. The study examined fish with different foraging strategies to determine if such differences affect heavy metal concentrations in the fish. The fish studied included the redear sunfish, a bottom feeder; largemouth bass, a predator at the top of the fish food chain; and bluegill sunfish, an omnivore. The Storm water ponds were associated with shopping center, apartment complex, and road construction projects. Wading birds were observed feeding in all selected storm water ponds. Natural lakes and ponds that did not receive any road or urban runoff were used as controls.	Significant concentrations of heavy metals were observed in the fish living in Storm water ponds, especially in the bottom-feeder, the redear sunfish. Redear sunfish collected from Storm water ponds contained mean cadmium, nickel, copper, lead, and zinc concentrations that were significantly higher than those from control sites. The effect on wading birds and other wildlife that are feeding on the fish living in Storm water ponds is unknown and was beyond the scope of the study. The authors suggest that, due to the results of the study, attracting wildlife to these ponds be discouraged.

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Sturm and Kirby (1991)	Studies focused on an evaluation of current design criteria and BMPs for controlling sediment in runoff from construction sites in response to legislation which established an effluent limit on turbidity. Grab samples were collected at the inlet to and outlet from sediment basins, and in the receiving stream at points upstream and downstream of the basin discharge point for several rainfall events. Samples were analyzed for suspended solids and turbidity. The turbidity standard for Georgia states that "discharges of Storm water runoff shall not exceed 50 NTU higher than the turbidity level of the receiving stream immediately upstream." The standard is 60 NTUs for roadway drainage construction sites.	The studies determined that the relationship between increases in suspended solids and turbidity as a measurement of water quality impairment varies with the soil type and the magnitude of the suspended sediment concentration. The probability of meeting the turbidity discharge standard was dependent on rainfall characteristics, the hydrologic condition and size of the watershed, soil properties and soil conservation measures, and sediment basin design. Results also suggested that an improvement in the design criteria for sediment basins would be to re-define the surface loading rate and to specify lower allowable values for solid with high percentages of clay.
Marsh (1993)	The objectives were to determine the biotoxicity of the nonpoint source runoff into the receiving waters of Jefferson County, KY and to determine whether there is a dilution factor in the toxicity of Storm water during the course of a storm. Over the course of one year, samples from six sites were analyzed for organic and inorganic compounds, pesticides, nutrients, dissolved solids, dissolved oxygen, turbidity, alkalinity, conductivity, hardness, pH, and temperature. The toxicity of the water was determined by bioassay of fathead minnows.	The study found that the contents of Storm water runoff from the Greater Louisville area were as varied as the sites where samples were collected and varied dramatically within a site from storm to storm. There were toxins in the runoff and sometimes the concentrations were exceedingly high. Pesticides, hydrocarbons, organic and inorganic compounds, low DO, high turbidity, and too many nutrients contributed to toxicity, but they were each a function of season, antecedent dry periods, and land uses. However, mortality in the bioassay was most affected by low DO concentrations in the runoff.
Lemly (1982)	Examined the water quality, substrate composition, and benthic insect populations in differently polluted zones of a small, southern Appalachian trout stream. Sediments in the Cullowhee Creek, NC were received from a feeder stream draining portions of the watershed disturbed by logging, residential construction, and livestock pastures.	Zones receiving sedimentation exhibited significantly degraded water quality with respect to bed load and pH at the substrate. These polluted zones also exhibited an extreme reduction in the abundance and diversity of filter feeding insects due to indirect effects of sedimentation which caused disruption of feeding and general habitat destruction. Addition of nitrates and phosphate, in association with sedimentation, resulted in growth of a filamentous bacterium which adversely affected insects.

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Gardner (1981)	Studied the effect of turbidity on the feeding rates of bluegills in a laboratory setting.	Found, under controlled circumstances, that turbidity significantly affected feeding rates. The experiment tested three levels of turbidity (60, 120, and 190 NTU) and found that feeding rates at the most turbid level declined by almost 50% as compared to the clearest level. The authors concluded that the reduction of feeding rates may occur in natural systems subject to periods of high concentrations of suspended sediments. The range of turbidity used in the study encompasses that found in North Carolina and may be typical of many southeastern US lakes and streams. In addition, turbidity in streams from watershed disturbed by construction or logging could exceed these levels.
Field and Pitt (1990)	Two studies examined the effects of urban runoff on aquatic organisms. One study examined Coyote Creek in San Jose, CA, a small stream only a few meters wide and less than a meter deep that drains a watershed of about 80,000 ha. Upstream flows are quite clean and downstream urban flows are highly variable and polluted. Another study compared two streams in Bellevue, WA, Kersey Creek an urban stream, and Bear Creek, a rural stream.	Both studies found significant impairment to aquatic life beneficial uses, but the possible causes were quite different. In Coyote Creek, impairment was attributed to major accumulation of toxic sediments. Kersey Creek suffered from increased flows, altered channel morphology and food availability, low DO concentrations, and various organic and metallic priority pollutants. The studies reveal that the effects of storm-induced discharges on aquatic, receiving-water organisms and other beneficial water uses is site-specific. Previous attempts to identify urban storm runoff problems using available data have not been conclusive because of differences in sampling procedures and the practice of pooling data from various sites. The long-term aquatic effects of urban runoff are probably more important than short-term effects associated with specific events. Further, long-term effects may only be expressed at great distances downstream from discharge location, or in accumulating areas (such as lakes).

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Steinman and McIntire (1990)	Describes the responses of periphyton communities to disturbances that change local environmental conditions and biological properties of the system in question. The disturbances examined in the paper are floods, desiccation, organic nutrient enrichment, and toxic pollutants.	A survey of the literature reveals that periphyton recovery patterns can be influenced strongly by site and disturbance type. For example, local environmental conditions, such as nutrient concentration, light level, grazing pressure, substrate size and composition, propagule abundance and source, sediment load, and stream order, grade, and channel geomorphology all can affect the recovery rates of periphyton. In addition, periphyton communities appear to take longer to recover from exposure to toxic metals than other disturbance types, perhaps because these metal remain in the system a relatively long time. Periphyton communities are crucial to stream ecosystem recovery because they serve as an important food resource for many invertebrates. Hence, if periphyton recovery is slow following a disturbance, other biological components in streams also may be slow to recover.